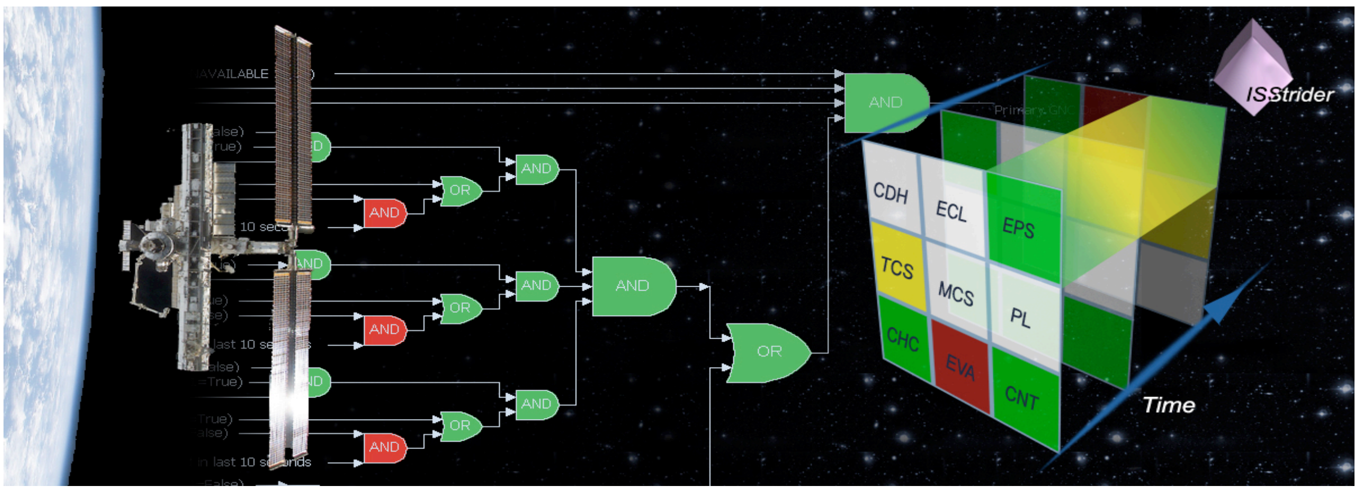
ISStrider: Model-based Mission Operations

The ISStrider project is developing model-based reasoning, visualization and document retrieval capabilities for mission and spacecraft operations. These include the Caution and Warning Fusion (CWF) capability for root-cause determination, the Caution and Warning Cube (CW^3) for visualization and the Real-time Knowledge Management (RKM) capability for document retrieval. We are applying these capabilities to the International Space Station (ISS) domain. The lessons we learn from the ISS legacy spacecraft will allow us to develop approaches applicable to future spacecraft and mission operations concepts.



Background

The International Space Station (ISS) is one of the most complex aerospace vehicles ever constructed. It is a unique spacecraft being developed using a staged approach. The challenge of the ISS staged approach is that human life must be sustained while the spacecraft is being constructed. This leads to extremely difficult constraints on the development of ISS, its software and its day-to-day control. The presence of several subsystems, some fully developed and others in the process of development, and their interaction with the control software (that is also being developed in a staged manner), can lead to unanticipated problems. The current on-board diagnostic system consists of a large set (~10K) of caution and warning (CW) events that fire in response to anomalies. In some cases, CW events fire en masse as a result of cascading effects and mission controllers and astronauts must determine root causes in order to resolve the anomalies. When ISS anomalies occur it drives up operations costs and reduces safety margins.

With over 10 interacting subsystems, controlled by 1 requires a very large team of mission controllers to analyze and resolve anomalies.

The goals of the ISStrider system are to reduce operations costs and increase safety margins through the use of model-based reasoning methods. NASA Ames Research Center (ARC) has been a leader in model-based reasoning methods for the past 15 years, developing real-time systems with several successful demonstrations and flight experiments: (i) In 1990, the Systems Autonomy Demonstration Project (SADP), (ii) in 1996 on the Deep Space 1 spacecraft, the Livingstone model-based reasoning system, (iii) later this year L2 will fly again on the EO-1 spacecraft.

Research Overview

ISStrider consists of three capabilities: Caution and Warning Fusion (CWF), Caution and Warning Cube (CW^3) and Real-time Knowledge Management (RKM). These three capabilities are developed as an Advanced Diagnostic System (ADS), which utilizes the Diagnostic Data Server (DDS) to subscribe to ISS telemetry as well as ISS training and simulation scenarios.

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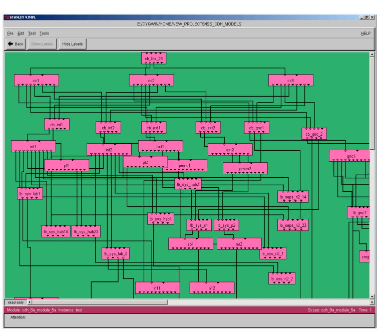
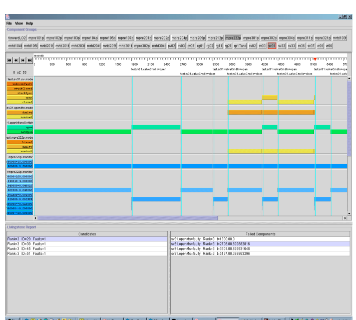
Caution and Warning Fusion (CWF) models the subsystems of the spacecraft and their interactions to provide a capability for enforcing global consistency between individual Caution and Warning events. Currently, mission controllers and astronauts are instructed to resolve each CW event in chronological order. However, if the CW events are related, than an integrated novel recovery may be the correct response. To determine common root-causes between CW events and suggest appropriate recovery actions, we are developing the CWF capability based upon a model-based diagnosis and recovery inference engine. We use the L2 inference engine, whose predecessor Livingstone flew on the Deep Space One spacecraft. L2 is a discrete-mode concurrent transition system which utilizes conflict-directed search methods to hone in on minimal diagnoses and recoveries. Currently work is being conducted on extending L2 into the modeling of software systems as well as continuous domains required to model subsystems including life-support and thermal.

Caution and Warning Cube (CW^3) provides advanced visualization GUI interfaces for users to rapidly scan (i) the time series of ISS Caution and Warning events and their logic, (ii) the time series of the L2 reasoning results, (iii) the mapping of the root-cause component(s) to the relevant portions of ISS and (iv) the explanations of the root-cause(s) and recovery action(s).

Real-time Knowledge Management (RKM) alleviates the challenge of finding the relevant documentation required to analyze ISS anomalies by indexing ISS documents to the L2 models of the ISS subsystems. When the CWF systems determines the root-cause(s), the relevant documentation is automatically presented to the mission controllers and the crew. This capability is being developed in cooperation with Netmark (NASA Ames). The planned types of documents indexed include CW fault tree logic, Architectural Design Documents (ADD), Interface Control Documents (ICD), source code, schematics, recovery procedure diagrams.





Relevance to Exploration Systems

The challenges of reduced mission operations costs and increased safety margins that we address in the ISS domain are relevant to Code T objectives for the development of sustainable missions. ISStrider contributes to sustainable future exploration by addressing the needs for (i) safety/reliability – make the onboard systems more locally self-reliant; (ii) affordability – reduce ground/onboard time to determine root cause; (iii) effectiveness – facilitate timely and accurate recovery from on-board failures.

H&RT Program Elements:
This research capability supports the following H&RT program /elements:
ASTP/Software, Intelligent Systems & Modeling
TMP/Advanced Space Operations

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